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Tundra burning in 2007 − Did sea ice retreat matter?

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Abstract

The goal of this study was to assess the importance of the 2007 sea ice retreat for hydrologic conditions on the Alaskan North Slope, and how this may have influenced the outbreak of tundra fires in this region. This study concentrates on two years, 2007 and 1996, with different arctic sea ice conditions and tundra fire activity. The year of 2007 is characterized by a low summer sea ice extent (second lowest) and high tundra fire activity, while 1996 had high sea ice extent, and few tundra fires. Atmospheric lateral boundary forcing from the NCEP/NCAR Reanalysis drove the Weather Research and Forecast (WRF) model, along with varying sea ice surface forcing designed to delineate the role of sea ice. WRF runs successfully reproduced the differences between 1996 and 2007. Surprisingly, replacing sea ice conditions in 1996 run by those from 2007 and vice versa (2007 run with 1996 sea ice) did not change the overall picture. The atmospheric circulation in August of 1996 included a significant low-pressure system over the Beaufort and Chukchi Seas. However, in 2007, a high-pressure system dominated the circulation over the Beaufort Sea. It is argued that this difference in large-scale patterns, rather than retreat of sea ice, was responsible for anomalously dry and warm atmospheric conditions over the North Slope in summer and autumn 2007, suitable for high tundra fire activity. Circulation in 2012 is contrasted with that in 2007 to further stress its importance for local weather on the North Slope.

Keywords: Tundra fire; Sea ice; Atmospheric circulation

1. Introduction

The Arctic has experienced recently and is projected to experience the largest warming compared to the rest of the globe. Observed changes include disappearing sea ice, degrading permafrost, and shifts in the seasonality of many variables, in particular those associated with precipitation (SWIPA, 2011). Changes in precipitation have important consequences for hydrologic regimes in Alaska, in particular on the North Slope.

Climatic change has also caused an increase in the area burned in many regions, particularly Alaska, where, during the modern record, the highest burned area and most extreme fire events occurred in the

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2000s (Kasischke et al., 2010). This has been accompanied by an increase in late-season burning due to the extreme fires that occur in remote areas that are not controlled. Evidence indicates that this intensification of the fire regime will continue into the future. Furthermore, as the overall vegetation biomass increases in the tundra (Euskirchen et al., 2009), with shrub encroachment observed throughout the Alaskan Arctic (Tape et al., 2006), the amount of fuel available for combustion by fire increases. While tundra fires on the North Slope of Alaska have been relatively rare events in the past, the large (1039 km^2) 2007 Anaktuvuk River fire that occurred here (Racine and Jandt, 2008; Jones et al., 2009; Hu et al., 2010) suggests that tundra fires may become more frequent as the climate warms and the fuel load increases. In fact, this fire was the largest and longest burning tundra fire ever recorded on the North Slope of Alaska, burning from July 16 – early October, 2007, and was also the largest fire recorded in Alaska in 2007 (Jones et al., 2009).

Tundra fires may act as a positive feedback to climate warming. They can release large amounts of carbon to the atmosphere since the tundra soils contain sizeable stores of organic carbon in their permafrost soil layers (Mack et al., 2011). In addition, the tundra surface albedo decreases by approximately 50–70% following fire (Rocha and Shaver, 2011), temporally increasing the net radiation and ground heat flux, but with a more persistent impact on thaw depth, which has implications for continued permafrost degradation and carbon release. Given the potential increase in tundra fires, and their associated positive feedbacks to climate, it is important to further understand the exact mechanisms that cause them so that they can be predicted in future years.

Anomalously dry and warm weather conditions on the North Slope in the summer of 2007 were responsible for the Anaktuvuk River fire (Jones et al., 2009; Hu et al., 2010). It was the driest in a 29-year (1979–2007) record of precipitation on the North Slope. Moreover, it also had the first and second longest sequence of days without precipitation, occurring between 1. July – 4. August and 16. August – 17. September, respectively (Jones et al., 2009). It is also notable that the 2007 tundra fire occurred during the same year as the second lowest summer sea ice extent recorded since the beginning of the satellite record in 1979. Hu et al. (2010) have put the low sea ice extent forward as one of the factors that could have contributed to the anomalous weather and the tundra fire. This leads to the question as to how the sea ice disappearance may impact the hydrology and climate on the North Slope of Alaska, and if indeed this sea ice reduction in 2007 may have contributed to the size and late season burning of the 2007 tundra fire. In order to answer this question, it is necessary to understand the overall atmospheric circulation and hydrological conditions in this region as they relate to sea ice.

Large-scale atmospheric circulation patterns in the Arctic changed considerably in recent decades (Zhang et al., 2008; Wu et al., 2012; Alexeev et al., 2012). Two large-scale atmospheric modes seem to have contributed most prominently to this change – the so-called Arctic Oscillation (AO, Thompson and Wallace (1998)) and pattern of transpolar drift (TD, Gudkovich, 1961), which has many different names and appearances – Barents Oscillation (Skeie, 2000; Tremblay, 2001), the dipole anomaly (Wu et al., 2006; Watanabe et al., 2006), and the Arctic Rapid change Pattern (Zhang et al., 2008). The importance of AO and TD patterns for arctic sea ice has been widely discussed in the literature with a general consensus that positive TD anomalies in the recent years are at least partially responsible for a few of the recent record minima in the sea ice extent. However, explaining how the atmospheric circulation and sea ice are coupled is not the subject of this paper. The goal of this research is to examine the link between summer sea ice extent and hydrologic regimes on land, and in particular how this may then influence tundra fire activity on the North Slope of Alaska. We examine these links during two years, 1996, when summer sea ice extent reached a recent local maximum and tundra fire activity was low, and 2007 when summer sea extent reached a second lowest minimum and the tundra fire activity was high. To this end, we will use a regional atmospheric model WRF (Weather Research and Forecasting, Michalakes et al., 2005) configured for the North Slope. WRF is a very well established and sophisticated model that is used widely in a variety of applications including weather forecasting and climate studies by many major centers in the world. The primary reason for using WRF in this study is because the relative role of lateral atmospheric boundary conditions can be measured against the role of surface forcing. WRF uses a detailed database of soil and vegetation that is adjusted to the modeled region during the initialization of the domain, which is important for proper description of surface conditions over land.

2. Experimental design

The positive phase of the AO is associated with lower than usual sea level pressure (SLP) and warmer